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Transistorized Circuits for the Fast Coincidence Experiments

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All electronic circuits for the detecting system of the charged particles emitted from the nuclear reaction are transistorized in our laboratory. They are used for fast coincidence experiments using solid state detectors. The characteristics of these circuits are described.

I. INTRODUCTION

Recently, nuclear reactions on light nuclei have been studied by the angular correlation experiment between two or more charged particles emitted. When a beam from a cyclotron is used in the coincidence experiment, the resolving time of the electronic system must be shorter than the repetition time interval of the bunched beam from the cyclotron so as to reduce the background due to accidental coincidences.

In our laboratory, charged particles from the nuclear reaction are usually detected by semiconductor detectors. The electric pulse signals from the detector have a fast rise time of few nano seconds, which is the electron collection time of the surface barrier detector. Then, the electronic circuits of the coincidence experiment should be suitable to the use of the solid state detectors.

The electronic circuits in our laboratory, *i.e.*, preamplifiers, monopolar linear amplifier, bipolar linear amplifier, pulse height discriminator, coincidence circuit, linear gate circuit, pulse stretching circuit and so on, have been transistorized in recent years except for the high voltage power source of the detector bias. Each transistorized circuit is constructed in a module box of AEC type, and BNC connectors are used for the input and the output. The coaxial cable connecting each circuit has a characteristic impedance of 75 ohms, then the input impedance of every circuits is chosen to avoid the mismatching at the point of the connection. The characteristics and the typical pulse forms from these circuits are described in the next sections.

II. CHARACTERISTICS OF EACH CIRCUIT

II-1 Preamplifier

A widely used charge sensitive preamplifier for the solid state detector has a rise time and a fall down time (decay time) of the order of micro seconds,

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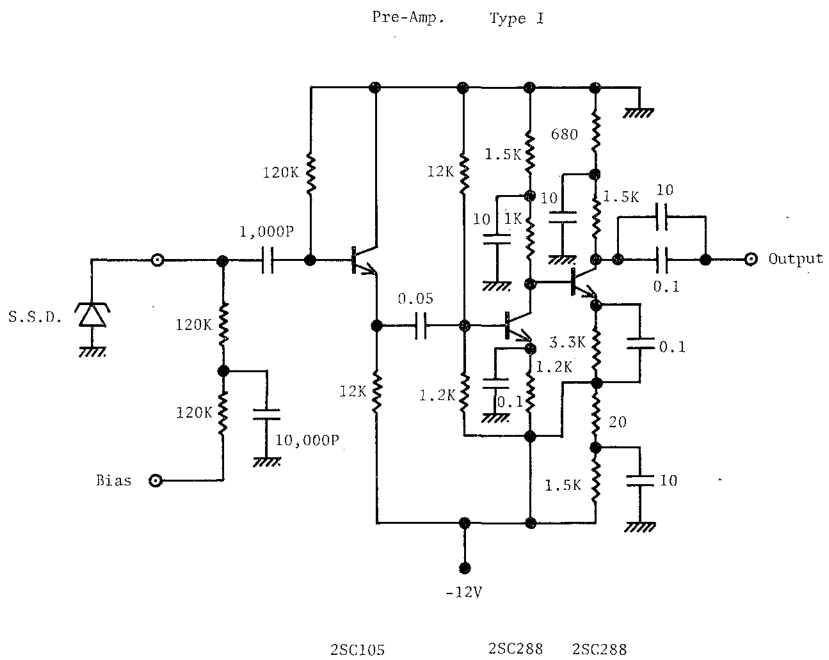


Fig. 1. Block diagram of the pre-amplifier of type I.

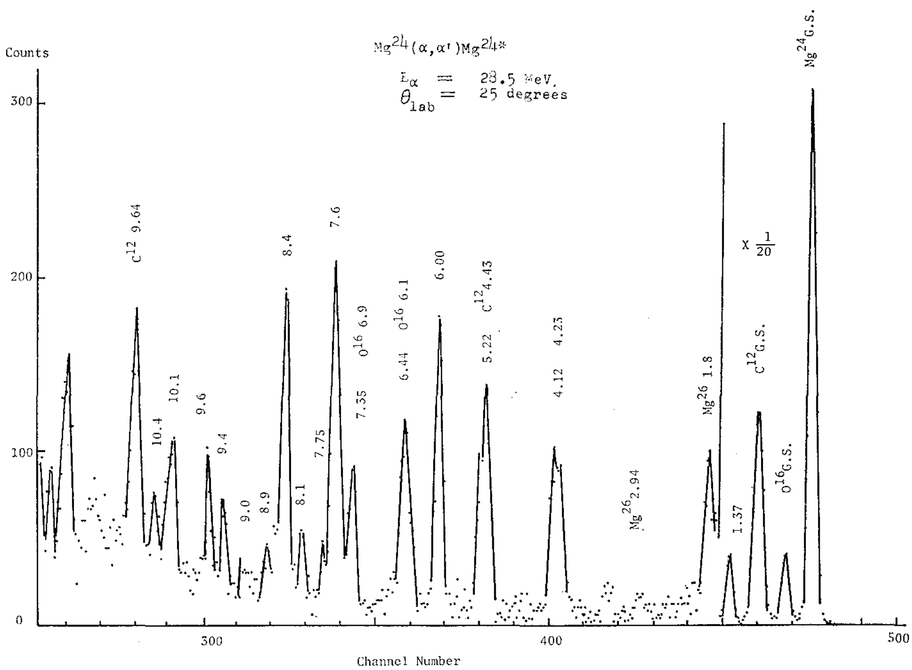


Fig. 2. A typical pulse height spectrum of alpha particles from the reaction $^{24}Mg(\alpha, \alpha')^{24}Mg^{*}$ using the pre-amplifier of type I.

and is not useful when the fast coincidence experiment is needed. Therefore, two types of transistorized fast preamplifier are constructed in our laboratory. Type I is a high input impedance preamplifier of voltage sensitive type, of which an emitter follower circuit is used in the input stage. The block diagram of this preamplifier is shown in Fig. 1. The preamplifier is composed of the emitter follower circuit and a feedback amplifier of gain ten. The rise time of this amplifier is shorter than 5 ns, and the output pulse is negative and falls down with the clipping time of 100 ns. The clipping time is chosen to suppress the slow component of the thermal noise of the transistor. The noise level in the output stage is less than 1 mV. A typical pulse height spectrum[1)] of alpha particles from the $^{24}Mg(\alpha, \alpha')^{24}Mg^*$ reaction at 28.5 MeV obtained with this preamplifier followed by a pulse stretching circuit, of which the explanation is given later, is shown in Fig. 2.

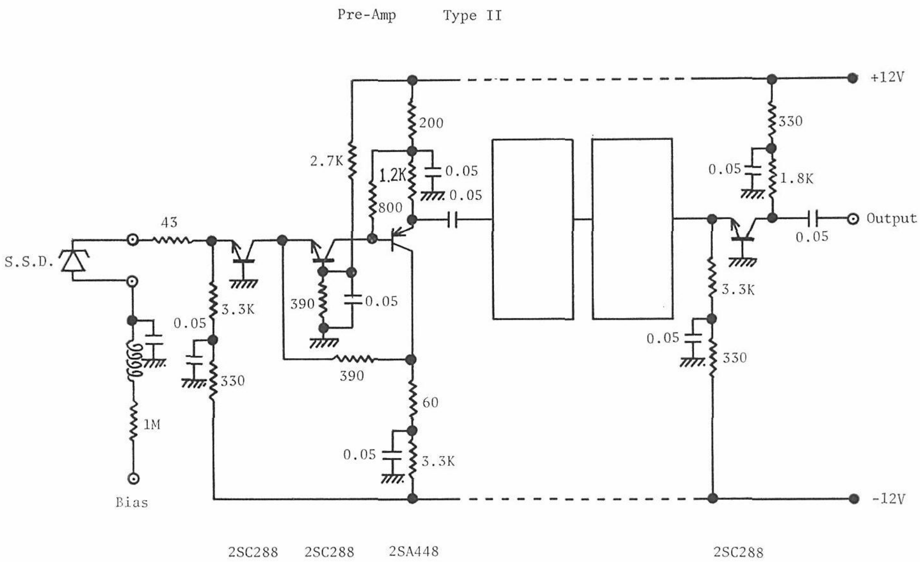


Fig. 3. Block diagram of the preamplifier of type II. A short coaxial cable is used to connect the solid state detector with the first stage transistor.

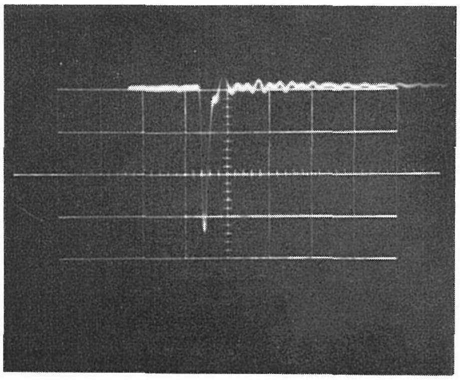


Fig. 4. A typical pulse form of alpha particles from Am source. The sweep time is 50 ns/cm.

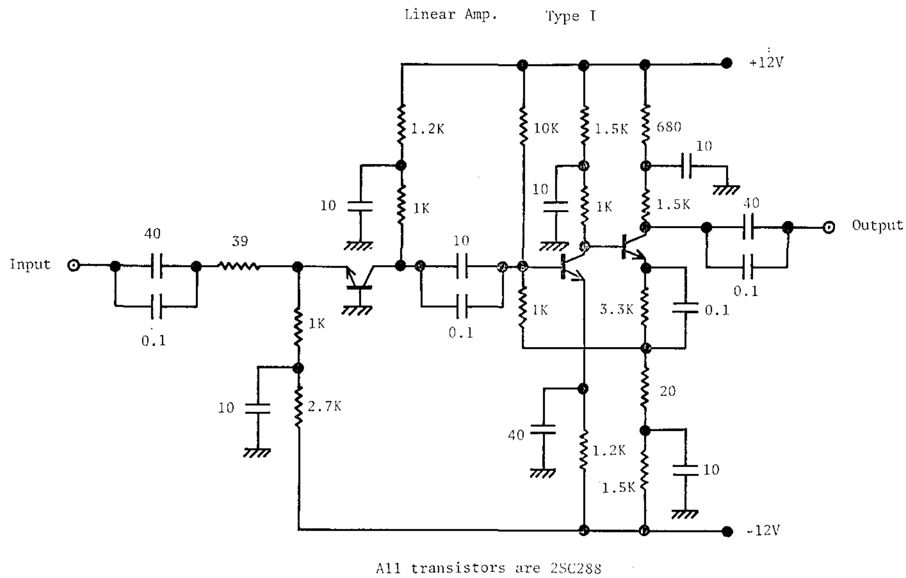
The overall energy resolution was better than 150 keV and the contribution from the preamplifier were estimated to be less than 30 keV by taking account of the effects of the finite angular resolution, the target thickness and the incident beam energy spread.

The type II preamplifier is a direct coupled current amplifier.[2] A common base transistor is coupled in series to a solid state detector as shown in Fig. 3, and the three stage amplifier follows also in series. The overall gain of 100 and the rise time of 3 ns of the negative pulse have been obtained. A typical pulse form corresponding to alpha particles emitted from an Am isotope is shown in Fig. 4. The pulse width is about 20 ns and the overall energy resolution of 250 keV is obtained in FWHM. In this case, a thin silicon surface barrier detector was used. Since the noise level of this circuit is about 2 mV, the signal to noise ratio is not so good as in the prescribed preamplifier.

When this pre-amplifier is used, the solid state detector must be insulated electrically from the earth potential.

II-2 Linear Amplifier

Output signals of the preamplifier are amplified usually by a linear amplifier, and fed to a discriminator or a pulse stretching circuit. A transistorized monopolar fast linear amplifier is a feedback type consisted with three micro disk silicon transistors. The block diagram of this circuit is shown in Fig. 5. Overall gain of 10 is obtained. The maximum output pulse height is a negative 1 V when the load impedance is 75 ohms. The rise time of the output pulse is about 4 ns, and the time delay between the input signal and the output signal has been estimated to be of several ns. Figure 6 shows the waveform of the input pulse and that of the output pulse using a mercury pulser which produces rectangular pulses.



ig. 5. Block diagram of the linear amplifier of type I.

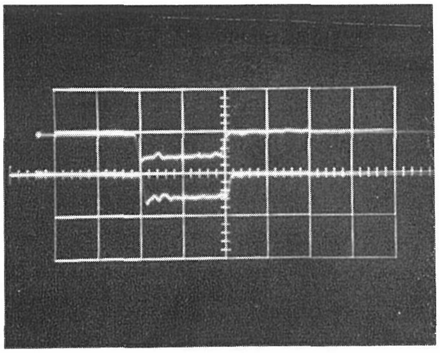


Fig. 6. The wave form of the output pulse from the amplifier of type I. The upper rectangular shape shows the input pulse from a mercury pulser with a delay line clipping and the lower rectangular shape shows the output signal from this amplifier. The sweep time of the osciloscope is 50 ns/cm. The vertical scale for the lower side signal is ten times larger than that for the upper side signal.

The second type linear amplifier is a bipolar amplifier for input signal of a negative long tail. The bipolar output pulse is gained with a double delay line clipping as shown in Fig. 7. The input and output pulse form are shown in Fig. 8 when the clipping time is adjusted as 50 ns. The clipping time is easily changed by the change of the length of two clipping cables. The rise time is about 10 ns and the minimum pulse width of about 50 ns has been obtained. The maximum output signal is a plus pulse of 5 V when the load impedance is 75 ohms and the minus pulse does not exceed 2 V, but the zero crossing time does not change even if the input pulse causes the saturation of the negative output pulse. The output signal of the bipolar amplifier can be fed to a crossover pick

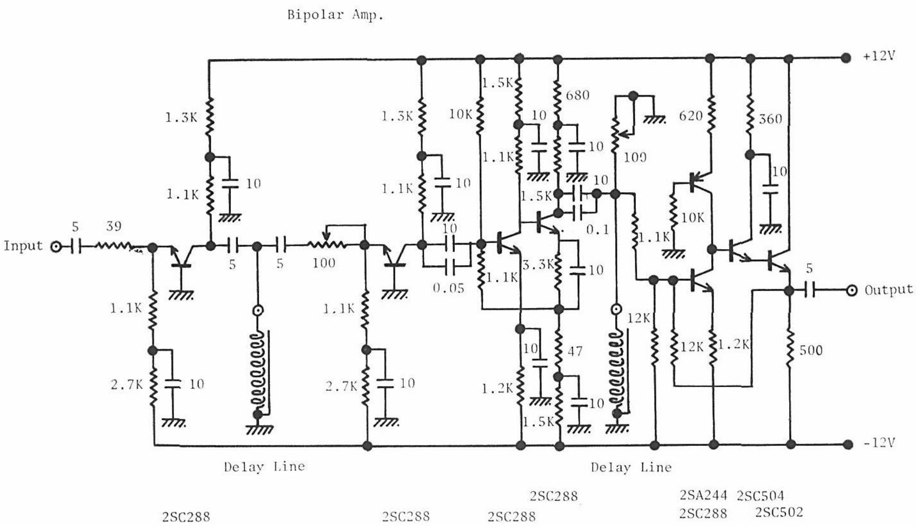


Fig. 7. Block diagram of the double delay line amplifier. The variable resistances are used to match the characteristic impedance of the clipping cables.

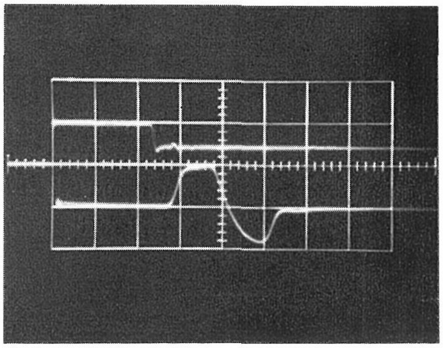


Fig. 8. Output pulse form of the type II amplifier. The input pulse is of a negative long tail. The upper stepped shape shows the input pulse from a mercury pulser and the lower bipolar shape shows the output signal of this amplifier. The sweep time is 50 ns/cm and the vertical scale corresponds to 0.1 V/cm and 2 V/cm for the long tail input signal and the bipolar output signal, respectively.

off circuit.

II-3 Discriminator

Block diagram of a pulse hight discriminator circuit[3] is shown in Fig. 9. An input negative pulse larger than 60 mV can be formed into a rectangular negative pulse, of which the width can be adjusted to a suitable time by changing the length of the coaxial cable. An example of the input and output pulse form is shown in Fig. 10. The pulse height of the output signal is nearly 1 V when the load impedance is 75 ohms. The time delay of the output signal is a function of the input pulse height as shown in Fig. 11. As shown in Fig. 12, the

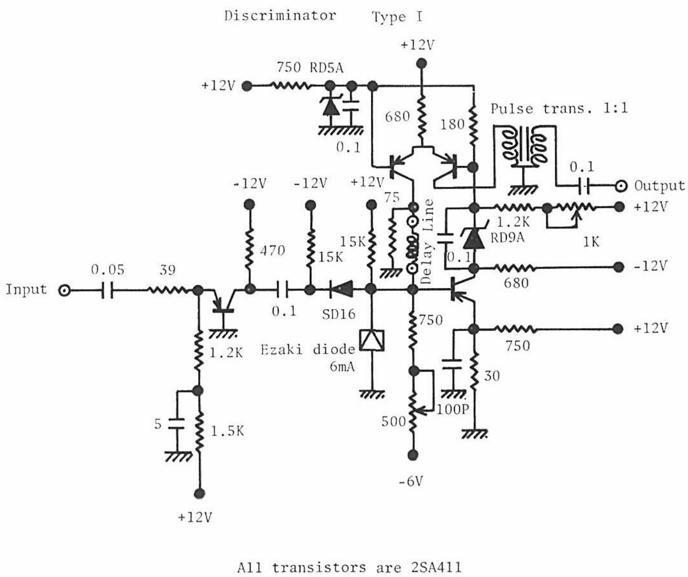


Fig. 9. Block diagram of the discriminator of type I.

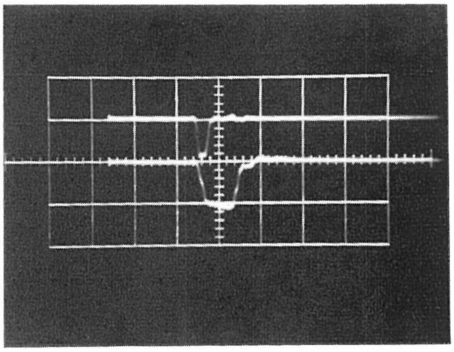


Fig. 10. The wave form of the output pulse from the type I discriminator. The input signal comes from a pulser. The upper rectangular form shows an input pulse from a pulser with a delay line clipping and the lower pulse shape shows the output signal wave form with the rectangular width of 40 ns. The sweep time of the osciloscope is 50 ns/cm. The vertical scale corresponds to 0.5 V/cm and 1 V/cm for the input signal and the output signal respectively.

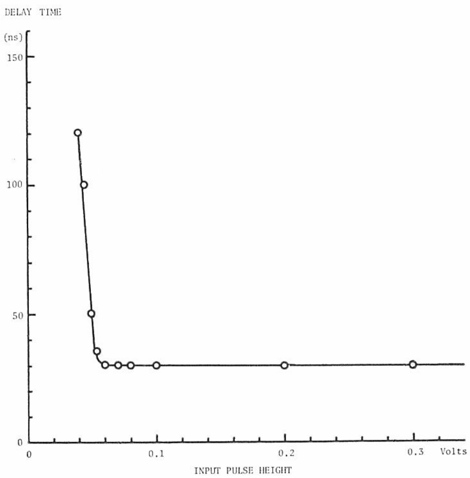


Fig. 11. Delay time of the output signal as a function of the input pulse height for the discriminator of type I.

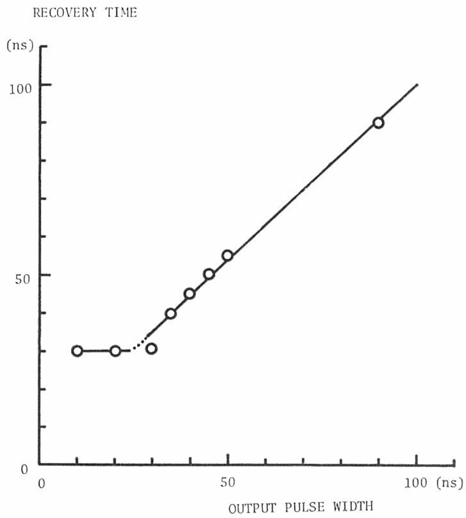


Fig. 12. Recovery time as a function of the output pulse width for the discriminator of type I.

recovery time, which is defined as the dead time minus output pulse width, is almost proportional to the output pulse width. The dead time equals nealy two times of the pulse width of the output signal.

The circuit of the discriminator is modified to use as a pulse shaper. This modified discriminator can not change the width of the output signal, because a fixed inductance is used instead of the coaxial delay line cable. A biased amplifier is added at the input stage to change widely the discriminating level. The block diagram of the first stage of the modified discriminator is given in Fig. 13.

The second type of the discriminator circuit[4] is shown in Fig. 14. This circuit has a dead time shorter than 75 ns, which is shorter than the interval

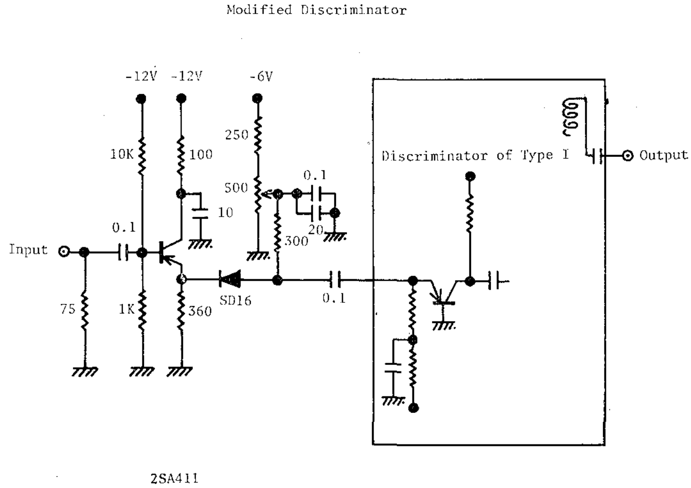


Fig. 13. Block diagram of the first stage of the modified discriminator.

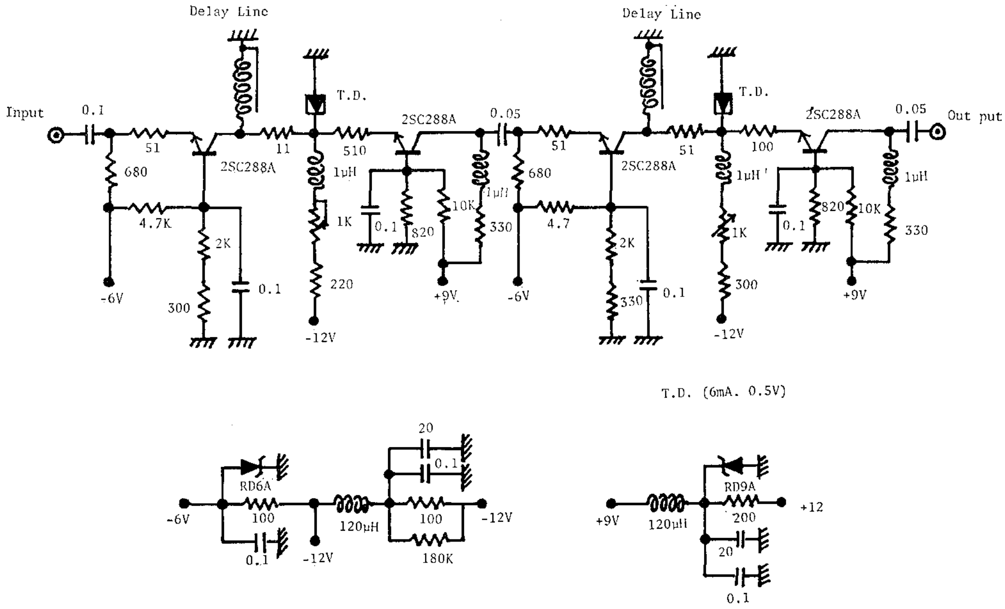


Fig. 14. Block diagram of the discriminator of type II.

time of the bunched beam from the cyclotron. Then, this discriminator can be used as a generator of the timing signal for a time of flight method. The delay time of the output signal is a function of the input pulse height as shown in Fig. 15. The typical output pulse form is shown in Fig. 16.

II-4 Coincidence circuit

Figure 17 shows a block diagram of the type I coincidence circuit. This circuit can be used for any negative pulses from the discriminators mentioned

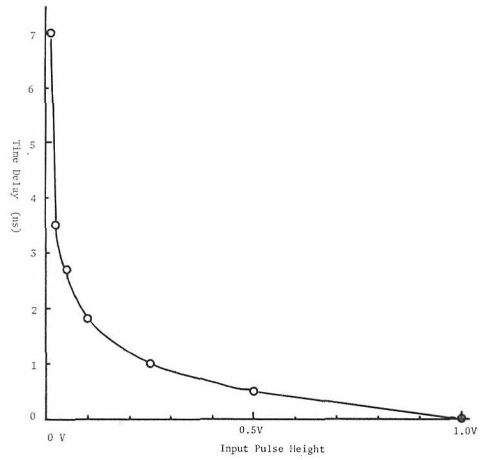


Fig. 15. Delay time of the output signal as a function of the input pulse height for the discriminator of type II.

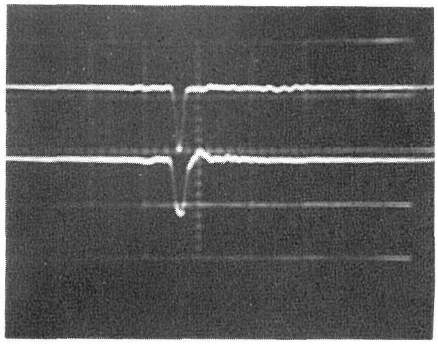


Fig. 16. A typical output pulse form of the discriminator of type II. The upper and lower redtangular pulse forms correspond to the input and output pulse forms respectively. The sweep time of the osciloscope is 50 ns/cm and the vertical scale corresponds to 0.1 V/cm.

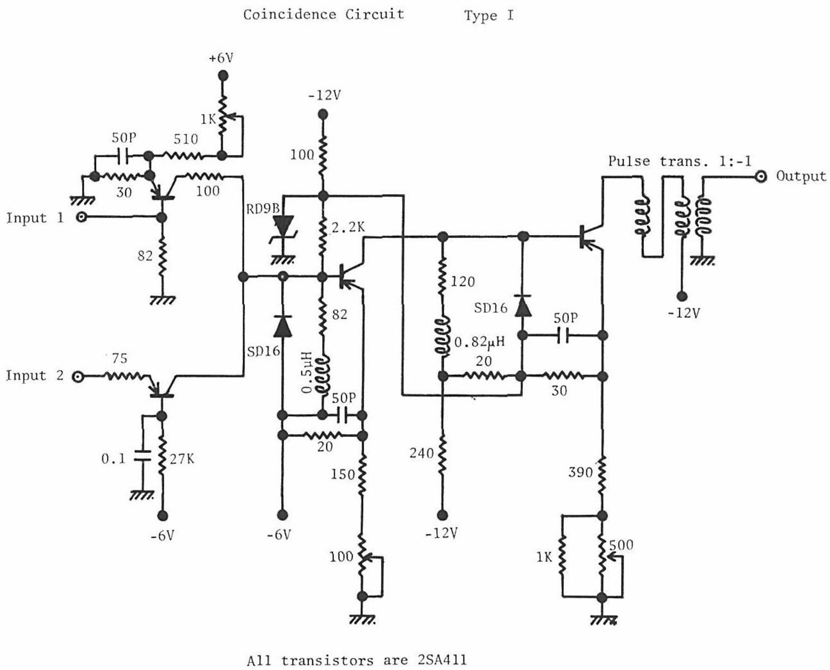


Fig. 17. Block diagram of the coincidence circuit of type I.

above. The resolving time of this circuit is equal to the sum of the widths of input signals. The output pulses are formed by a pulse shaper.

Type II coincidence circuit is equipped with the pulse clipping circuit as shown in Fig. 18. The resolving time of this circuit is determined by the length

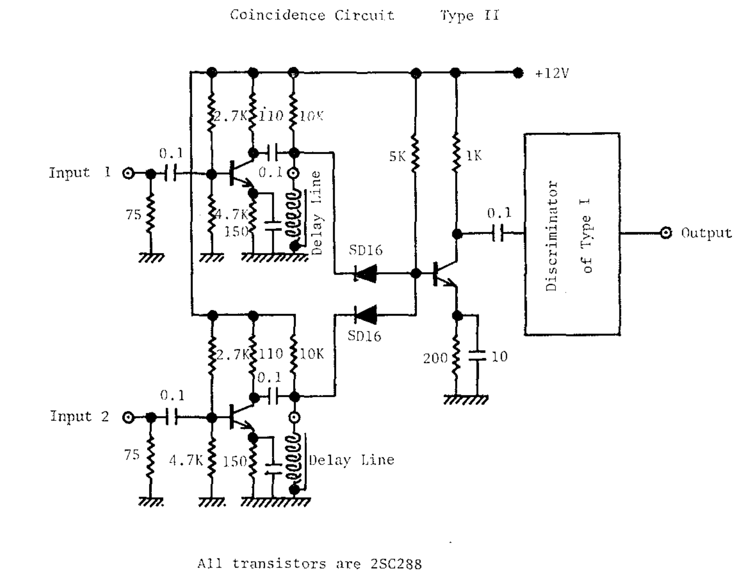


Fig. 18. Block diagram of the coincidence circuit of type II.

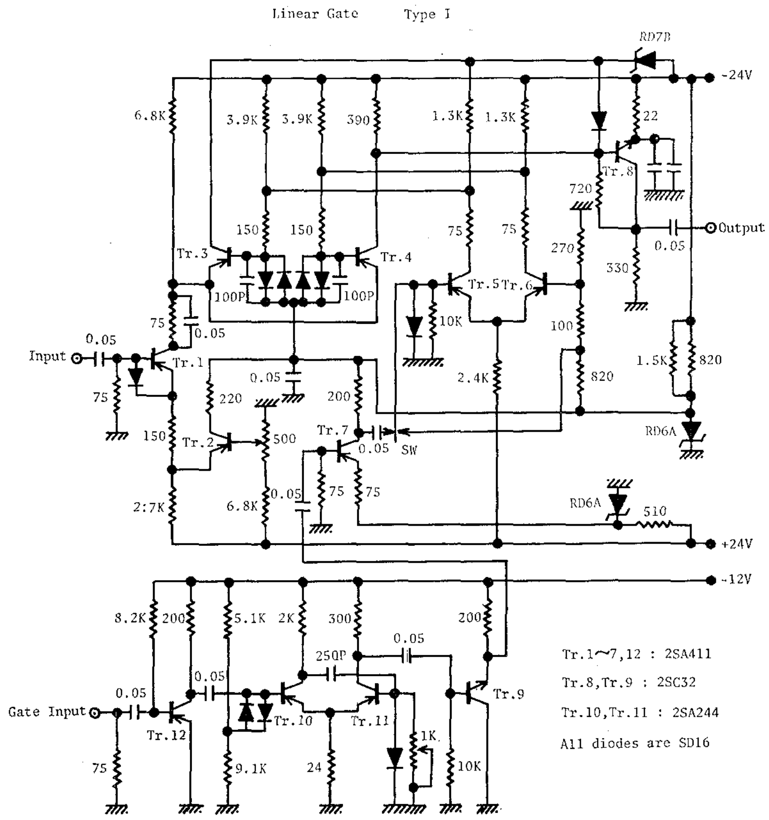


Fig. 19. Block diagram of the linear gate circuit of type I.

of two clipping cables. The output signals of the modified discriminator are suitable for the input signal of this circuit.

II-5 Linear Gate Circuit

Figure 19 shows a block diagram of a linear gate circuit. This is composed of a gate pulse generator circuit and a linear gate circuit. The former produces the positive gate pulse with a suitable width from 50 ns to 200 ns. An output pulse form of the linear gate circuit is shown in Fig. 20 in comparison with the

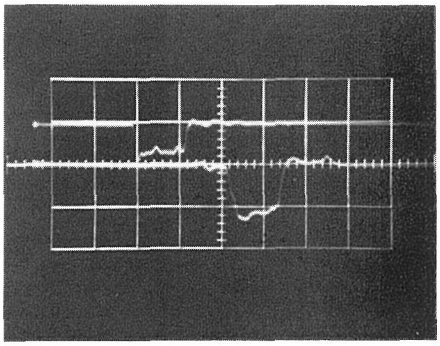


Fig. 20. Output pulse form of the linear gate circuit of type I for the rectangular input pulses. The upper and lower pulse form show the input pulse form and the output pulse form respectively. The sweep time of the osciloscope is 50 ns/cm and the vertical scale is 1 V/cm for both pulse. The effects of the gate signal are slightly seen before and after the main rectangular pulse.

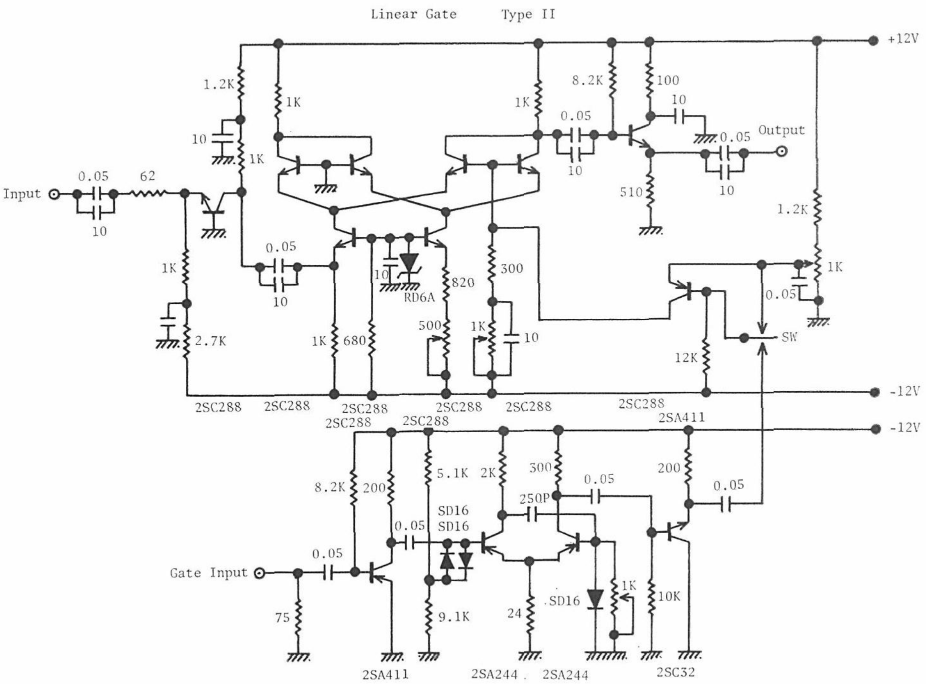


Fig. 21. Block diagram of the linear gate circuit of type II.

input pulse. The pedestal due to the gate signal is adjustable with a variable resistance in the front panel. In Fig. 20, two small kick pulse about 0.1 V are shown because of the effect of the gate signal. The gain of about 1.3 is obtained and the pulse height of the output signal is proportional to the input signal up to the saturation signal of 1.5 V.

Figure 21 shows a block diagram of the other type of the linear gate circuit. The output pulse is half of the input pulse in height. The output and input pulse form using a pulser are shown in Fig. 22. The effect of the pedestal due to the gate signal is small and less than 0.04 V.

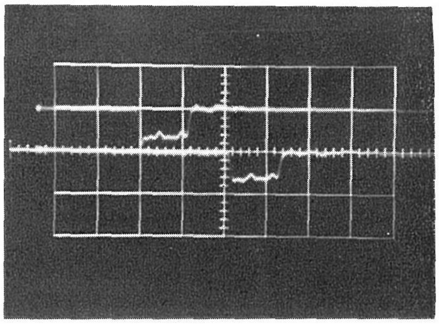


Fig. 22. Output pulse form of the linear gate circuit of type II for the rectangular input pulses. The upper and the lower pulse shape show the input and the output pulse form respectively. The sweep time of the osciloscope is 50 ns/cm and the vertical scale 1 V/cm.

II-6 Pulse Stretcher

Negative sharp pulses of the width of several tens ns can be stretched into pulses of ms decay time by a pulse stretching circuit. The block diagram of the stretcher is shown in Fig. 23. The circuit has a simple *RC* integrating circuit

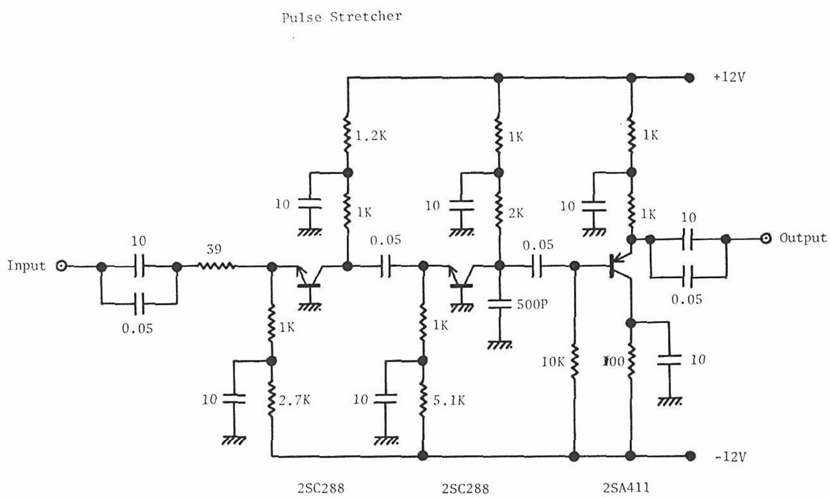


Fig. 23. Block diagram of the pulse stretcher.

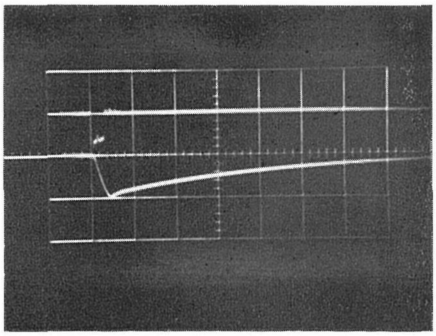


Fig. 24. Output pulse form of the pulse stretcher for the rectangular input signals. The upper and lower pulse form show the input and output pulse forms respectively. The rise time of the lower pulse is the same as the pulse width of the upper pulse. The sweep time is 200 ns/cm and the vertical scale is 1 V/cm.

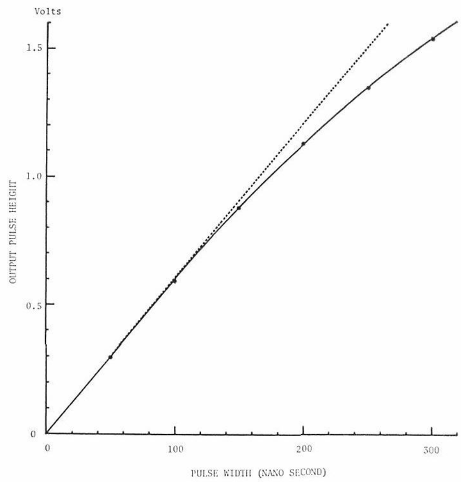


Fig. 25. Output pulse height as a function of the input pulse width using the pulse stretcher when the pulse height of the input signal is fixed at 1 V.

with a time constant of about one ms. The output signal form from the pulse stretcher using a pulser is shown in Fig. 24 in comparison with the input signal. The pulse height of the output signal is proportional to the input signal up to the output pulse height of 6 V. The relation between the output pulse height and the input pulse width is shown in Fig. 25 in the case of the input pulse of 1 V.

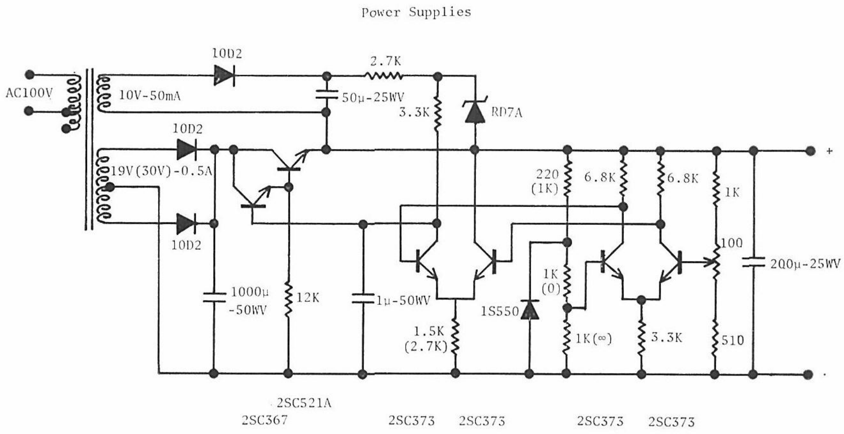


Fig. 26. Block diagram of the transistorized circuit of the power supply of 12 V. The value in parentheses corresponds to the power of 24 V.

II-7 Power Sources

Each transistorized circuit is composed in a module and set in an AEC type bin. The bin supplies four kinds of constant voltage power to each module. The stabilized power source is composed of transistorized circuit, of which the block diagram is shown in Fig. 26. The maximum available current of these power sources are about 1 A with the ripple of 1 mV and the voltage drift per a day is 0.5%.

Figure 27 shows the configuration of pins in the connector of power sources to the module.

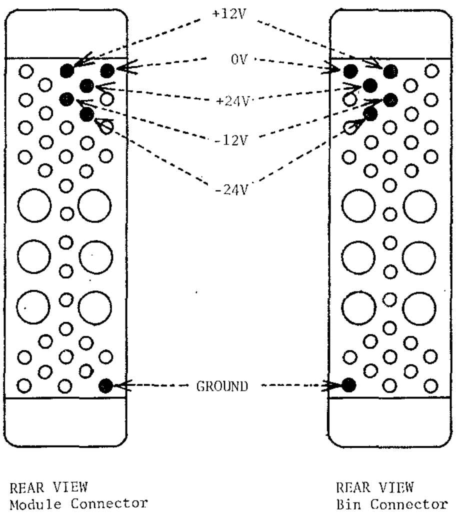


Fig. 27. Rear view of the connectors.

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